Eastern Interconnection
Wind Integration and Transmission Study

Technical Review Committee

Kick-Off Meeting

August 19, 2008

Saint Paul, Minnesota

EnerNex CORPORATION

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Morning Agenda

8:30 am	Project Overview & Objectives	Dave Corbus (NREL)
	Meso-scale Modeling	??
10:15 am	Break	
10:30 am	Project Plan	EnerNex
11:15 am	Overview of Analytical Methodology	EnerNex
11:45 am	Lunch	

Afternoon Agenda

12:45 pm	Data, Tools, and Models	
	➢ Meso-scale data management and analysis	EnerNex
	➢ PowerBase	MISO/Ventyx
	➢ PROMOD IV	MISO/Ventyx
	➢ GE MARS	Miso
	Developing the Transmission Scenario	MISO
	➢ JCSP Methodology	
	➢ Process for overlay development	
2:45 pm	Break	
3:00 pm	Issues and Assumptions	EnerNex
	➢ Markets	
	○ Structure	
	○ Products	
	○ Variability across footprint	
	➢ Non-market areas	
	➢ Canada	
	➢ Modeling questions & challenges	
	○ Intra-hour constraints	
	○ Contingency reserves	
	○ Assumptions for load and wind generation forecast horizon	
	○ HVDC line modeling	
	➢ Critical inputs	
	○ Fuel prices	
	○ Carbon costs	
	○ Market hurdle rates	
4:15 pm	Discussion & Summary	EnerNex/NREL
	➢ Action items	
	➢ Follow-up	
	➢ Next meeting	

Meeting Objectives

- Describe Study Objectives
- Present Project Plan
- Review Proposed Analytical Methodology
- Discuss Data, Models, and Tools
- Discuss Myriad of Assumptions and Issues related to analysis

PROGRAM PLAN

Project Team

- EnerNex Corporation
  - Bob Zavadil
  - Jack King
- Midwest ISO
  - John Lawhorn
  - Dale Osborn
  - JT Smith
- Ventyx
  - Brenton Meese
  - Gary Moland
  - Rick Hunt

Project Task Structure

- Task 1: Preliminary Analysis
- Task 2: Baseline Scenario
- Task 3: Transmission Expansion Plan
- Task 4: High Wind Scenario for 2024
- Task 5: High Wind Scenario for 2024 with Variations
- Task 6: LOLE and ELCC Analysis
- Task 7: Draft and Final Reports

Task 1: Preliminary Analysis

- Objective
  - Characterize meso-scale wind production data from NREL dataset
    - » Production attributes
    - » Energy value
    - » Issues for delivery
  - Define base and alternate scenarios for 20% and 30% penetration by energy in Eastern Interconnection
    - » 20%: 240 GW
    - » 30%: 360 GW
- Issues
  - Full mesoscale data set not available until end September
  - Next TRC scheduled for <mid-October

Approach for Analyzing Mesoscale Data

a) *Group wind sites into 20-30 regions.*

b) *Conduct statistical analysis with spatial and temporal slices, to examine resource correlation across the region and wind/load correlation over time.*

c) *Examine the energy production value of wind sites.*

d) *Examine the transmission capability between wind regions.*

e) *Develop preliminary costs for each wind region based on statistical analysis, production value, and transmission capability.*

-----------------TRC Meeting #2 will be here------------------------

f) *Develop two scenarios with 20% and 30% wind energy penetration in the study footprint based on these analyses, and with a goal of low cost of energy and low integration costs.*

g) *Conduct statistical analysis on these two scenarios to examine the feasibility of integrating these levels of resources into the individual control areas.*

h) *Analyze two variations of the 20% and/or 30% wind energy scenarios (2 additional scenarios) to address stakeholder issues. These two additional scenarios may include variations in the geographic spread of wind plant sites, a "best correlated with load" scenario; a scenario that looks at least-cost transmission considerations, and other scenarios as identified by the TRC.*

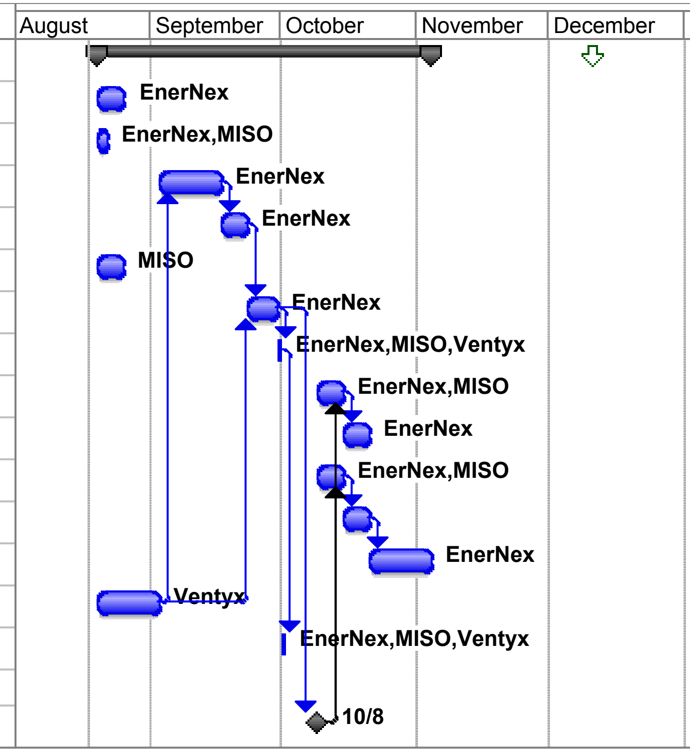
i) *Present the preliminary analysis and proposed scenarios to the TRC.*

“Wind Region” Definitions

- Based on “LOLE” zones for existing transmission network
- Provides means for identifying inter-regional transmission constraints
- Definitions will be retained for later LOLP and ELCC analysis to gauge impact

Task Schedule

ID	Task Name
4	**Preliminary Analysis**
5	Database development
6	Group wind sites
7	Conduct general statistical analysis
8	Calculate energy production value
9	Examine transmission capability
10	Develop preliminary cost estimates
11	TRC meeting preparation
12	Develop scenarios for 20% and 30% penetration
13	Conduct statistical analysis for 20% and 30% scenarios
14	Develop variations on 20% and 30% scenarios
15	Conduct statistical analysis for alternat 20% and 30% scenarios
16	Summarize analysis
17	Develop Eastern Interconnection load data setsfor 2004-2006
18	TRC meeting preparation
19	
20	TRC Meeting #2

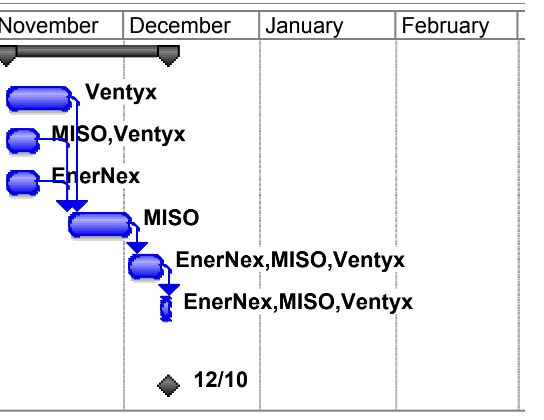


Task 2: Baseline Scenario

- Objective
  - Provide a reference point for high penetration wind scenarios
  - Assess wind integration impacts for a near-term scenario
- Issues
  - JCSP 5% case reference case was proposed as baseline
  - Includes approx. 5% wind generation based on state mandates
  - transmission expansion developed by JCSP
  - Load forecast data?
- Predecessor Tasks
  - Wind data from mesoscale database for defined scenario
  - Load pattern data based on 2004, 2005, and 2006
  - PROMOD testing on full Eastern Interconnection model

Baseline Scenario

ID	Task Name
22	**Baseline Scenario**
23	PROMOD application testing
24	Refine JCSP 5% model as necessary
25	Calculate intra-hour requirements for JCSP 5% scenario
26	Execute production simulations for JCSP 5% scenario
27	Analyze production simulations to assess integration impacts
28	TRC meeting preparations
29	
30	TRC Meeting #3

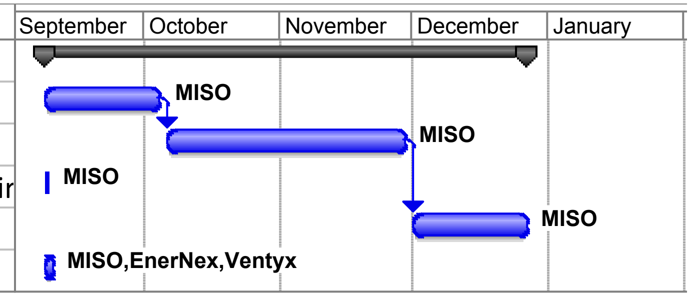


Task 3: Transmission Expansion Plan

- Objective
  - Develop necessary transmission expansion plans for 20% and 30% wind scenarios
- Issues
  - JCSP process is the model
  - Time frame considerably compressed for this study
  - Discussion and review by JCSP members considered critical
  - Possibility that existing 20% JCSP plan will be applicable here
- Predecessor Tasks
  - Definition of wind generation scenarios
  - Some work may begin immediately

Transmission Expansion Plans

ID	Task Name
32	**Transmission Planning Studies**
33	Refine JCSP 20% overlay for study scenario
34	Develop preliminary overlay for 30% scenario
35	Assess impacts of alternate wind scenarios on transmission requir
36	Convene JCSP to review new transmission overlays
37	TRC meeting preparations



Task 4: 2024 Scenario with High Wind

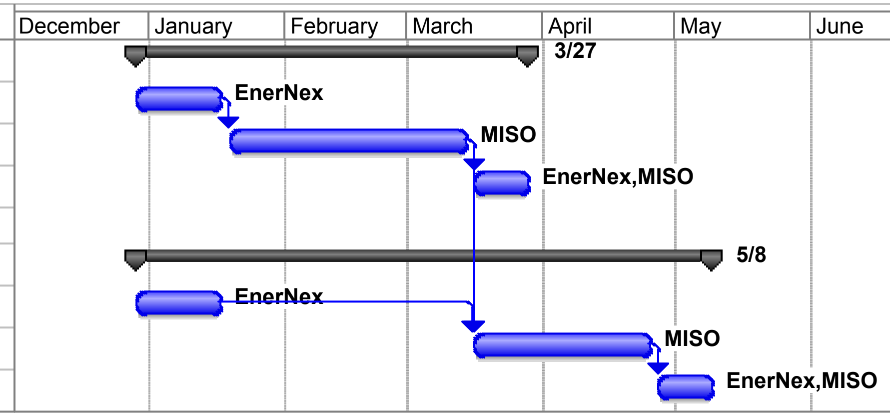
- Objective
  - Analyze impacts of 20% and 30% base wind scenarios
- Issues
  - Modeling assumptions
  - Optimization, given model complexity and make-up
- Predecessor Tasks
  - Wind scenario data from mesoscale database for all three pattern years
  - Consensus on modeling assumptions and data input
  - Calculations of intra-hour impacts

Task 5: 2024 with Alternate Wind

- Issues
  - Adjustments to Transmission Expansion Plan
  - Where does the additional 120 GW go?
- Predecessor tasks
  - Task can be performed roughly in parallel with Task 4
  - Human and computer resource constraints(?)

Tasks 4 and 5

ID	Task Name
41	**Year 2024 with High Wind Scenario**
42	Assess intra-hourly impacts for 20% and 30% scenarios
43	Execute production simulations (base)
44	Summarize results and findings
45	
46	**Year 2024 with Variations on High Wind Scenario**
47	Assess intra-hourly impacts for alternate 20% and 30% scenarios
48	Execute production simulations (alternate)
49	Summarize results and findings

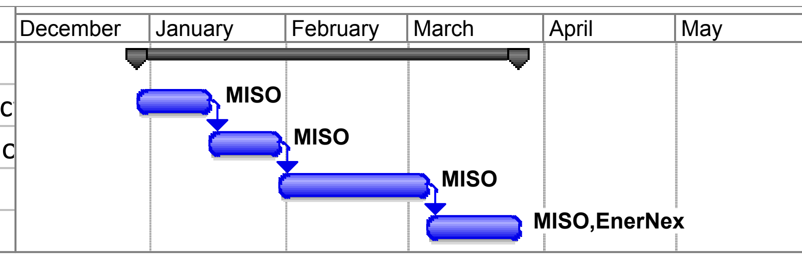


Task 6: LOLP and ELCC Analysis

- Objective
  - Determine contribution of wind generation to Eastern Interconnection reliability
  - Assess reliability value of transmission only(?)
- Issues
  - Transmission overlay could have significant impact on existing LOLE zones
  - Transmission will serve as capacity resources for some zones; may make some zones very reliable, such that ELCC of wind would be minimal
- Predecessor tasks
  - Requires PROMOD to determine new are import limits
  - GE MARS model to be developed from PowerBase
  - Resource constraints may necessitate staging

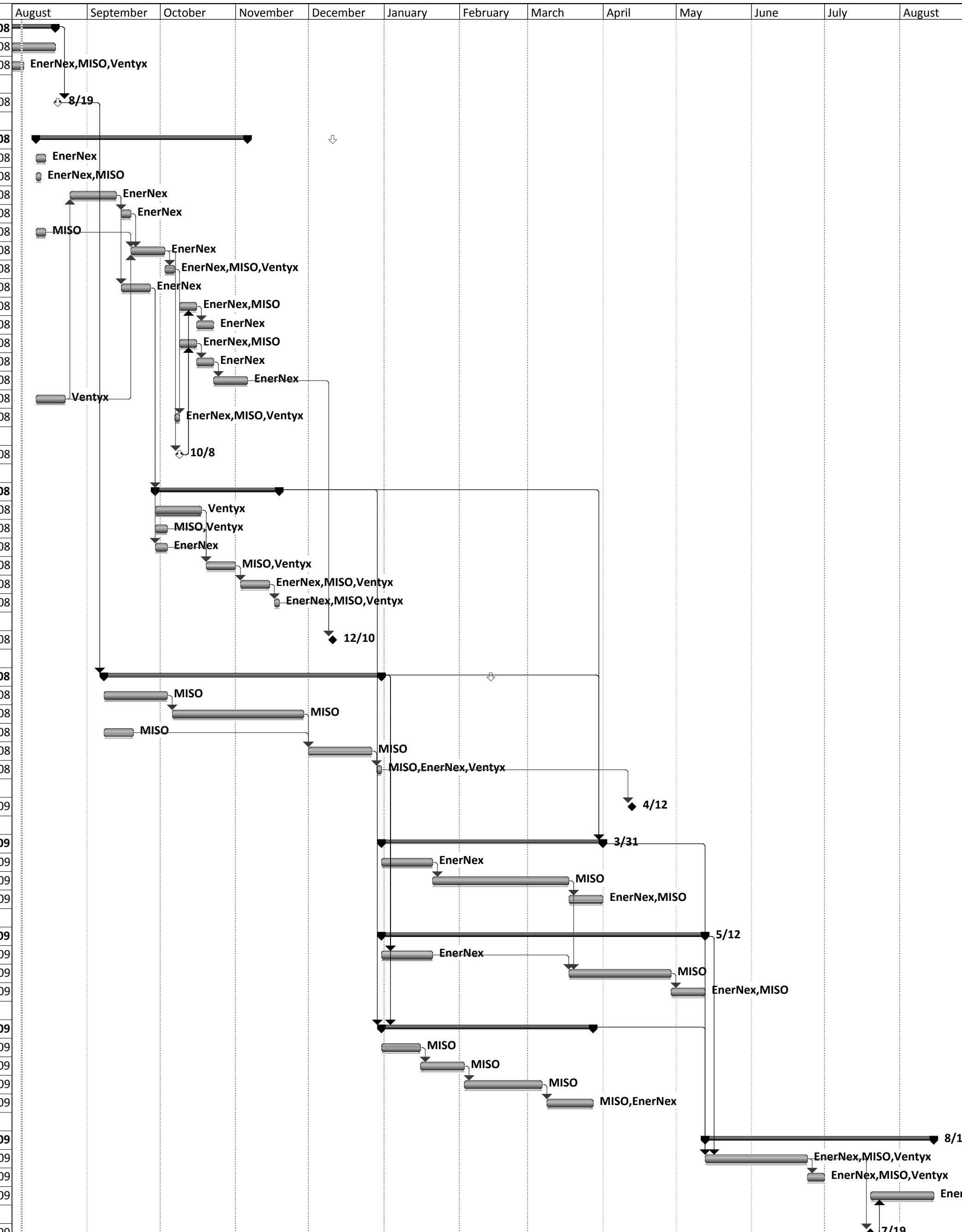
Task 6

ID	Task Name
51	**ELCC and LOLP Analysis**
52	Construct model for GE MARS using Powerbase data from produc
53	Assess import limits for each LOLE zone based on new transmissic
54	Run MARS to evaluation LOLP and ELCC for wind generation
55	Analyze results and develop conclusions



Schedule

ID	Task Name	Duration	Start	Finish
1	**1 Project Planning**	**12 days**	**Fri 8/1/08**	**Mon 8/18/08**
2	1.1 Program Plan	12 days	Fri 8/1/08	Mon 8/18/08
3	1.2 TRC meeting preparations	3 days	Fri 8/1/08	Tue 8/5/08
4				
5	**2 TRC Meeting #1**	1 day	Tue 8/19/08	Tue 8/19/08
6				
7	**3 Preliminary Analysis**	**63 days**	**lon 8/11/08**	**Wed 11/5/08**
8	3.1 Database development	4 days	Ion 8/11/08	Thu 8/14/08
9	3.2 Group wind sites	2 days	Ion 8/11/08	Tue 8/12/08
10	3.3 Conduct general statistical analysis	15 days	Ion 8/25/08	Fri 9/12/08
11	3.4 Calculate energy production value	4 days	Ion 9/15/08	Thu 9/18/08
12	3.5 Examine transmission capability	4 days	Ion 8/11/08	Thu 8/14/08
13	3.6 Develop preliminary cost estimates	10 days	Fri 9/19/08	Thu 10/2/08
14	3.7 TRC meeting preparation	2 days	Fri 10/3/08	Mon 10/6/08
15	3.8 Develop wind data for 5% JCSP scenario	10 days	Ion 9/15/08	Fri 9/26/08
16	3.9 Develop scenarios for 20% and 30% penetration	5 days	Thu 10/9/08	Wed 10/15/08
17	3.10 Conduct statistical analysis for 20% and 30% scenarios	5 days	hu 10/16/08	Wed 10/22/08
18	3.11 Develop variations on 20% and 30% scenarios	5 days	Thu 10/9/08	Wed 10/15/08
19	3.12 Conduct statistical analysis for alternat 20% and 30% scenarios	5 days	hu 10/16/08	Wed 10/22/08
20	3.13 Summarize analysis	10 days	hu 10/23/08	Wed 11/5/08
21	3.14 Develop Eastern Interconnection load data setsfor 2004-2006	10 days	Ion 8/11/08	Fri 8/22/08
22	3.15 TRC meeting preparation	2 days	Tue 10/7/08	Wed 10/8/08
23				
24	**4 TRC Meeting #2**	1 day	Ved 10/8/08	Wed 10/8/08
25				
26	**5 Baseline Scenario**	**37 days**	**lon 9/29/08**	**Tue 11/18/08**
27	5.1 PROMOD application testing	15 days	Ion 9/29/08	Fri 10/17/08
28	5.2 Refine JCSP 5% model as necessary	5 days	Ion 9/29/08	Fri 10/3/08
29	5.3 Calculate intra-hour requirements for JCSP 5% scenario	5 days	Ion 9/29/08	Fri 10/3/08
30	5.4 Execute production simulations for JCSP 5% scenario	10 days	on 10/20/08	Fri 10/31/08
31	5.5 Analyze production simulations to assess integration impacts	10 days	Ion 11/3/08	Fri 11/14/08
32	5.6 TRC meeting preparations	2 days	on 11/17/08	Tue 11/18/08
33				
34	**6 TRC Meeting #3**	1 day	ed 12/10/08	Wed 12/10/08
35				
36	**7 Transmission Planning Studies**	**82 days**	**Mon 9/8/08**	**Tue 12/30/08**
37	7.1 Refine JCSP 20% overlay for study scenario	20 days	Mon 9/8/08	Fri 10/3/08
38	7.2 Develop preliminary overlay for 30% scenario	40 days	Ion 10/6/08	Fri 11/28/08
39	7.3 Assess impacts of alternate wind scenarios on transmission requirements	10 days	Mon 9/8/08	Fri 9/19/08
40	7.4 Convene JCSP to review new transmission overlays	20 days	Ion 12/1/08	Fri 12/26/08
41	7.5 TRC meeting preparations	2 days	on 12/29/08	Tue 12/30/08
42				
43	**8 TRC meeting #4**	1 day	Fri 4/10/09	Sun 4/12/09
44				
45	**9 Year 2024 with High Wind Scenari0**	**65 days**	**ed 12/31/08**	**Tue 3/31/09**
46	9.1 Assess intra-hourly impacts for 20% and 30% scenarios	15 days	ed 12/31/08	Tue 1/20/09
47	9.2 Execute production simulations (base)	40 days	Ved 1/21/09	Tue 3/17/09
48	9.3 Summarize results and findings	10 days	Ved 3/18/09	Tue 3/31/09
49				
50	**10 Year 2024 with Variations on High Wind Scenario**	**95 days**	**ed 12/31/08**	**Tue 5/12/09**
51	10.1 Assess intra-hourly impacts for alternate 20% and 30% scenarios	15 days	ed 12/31/08	Tue 1/20/09
52	10.2 Execute production simulations (alternate)	30 days	Ved 3/18/09	Tue 4/28/09
53	10.3 Summarize results and findings	10 days	Ved 4/29/09	Tue 5/12/09
54				
55	**11 ELCC and LOLP Analysis**	**63 days**	**ed 12/31/08**	**Fri 3/27/09**
56	11.1 Construct model for GE MARS using Powerbase data from production simulations	12 days	ed 12/31/08	Thu 1/15/09
57	11.2 Assess import limits for each LOLE zone based on new transmission overlays	12 days	Fri 1/16/09	Mon 2/2/09
58	11.3 Run MARS to evaluation LOLP and ELCC for wind generation	24 days	Tue 2/3/09	Fri 3/6/09
59	11.4 Analyze results and develop conclusions	15 days	Mon 3/9/09	Fri 3/27/09
60				
61	**12 Draft and Final Reports**	**68 days**	**/ed 5/13/09**	**Fri 8/14/09**
62	12.1 Compile draft report	30 days	Ved 5/13/09	Tue 6/23/09
63	12.2 TRC meeting preparations	5 days	Ved 6/24/09	Tue 6/30/09
64	12.3 Revise draft report per TRC discussion and input	20 days	Ion 7/20/09	Fri 8/14/09
65				
66	**13 TRC Meeting #5**	1 day	Fri 7/17/09	Sun 7/19/09



ANALYTICAL METHODOLOGY

General

- Analysis will consist of
  - Statistical characterization of mesoscale data on SQL server platform
  - Hourly production simulations to assess operational impacts
  - Assessment of reliability with Monte Carlo-based probabilistic algorithm
- Specific tools
  - SQL server
  - PROMOD IV
  - Energy Velocity Suite
  - GE MARS

Production Simulation Methodology

- Case comparison approach
  - Actual wind vs. “ideal” wind
  - Objective is to determine relative value of two resources providing same amount of annual/daily energy
- Issues
  - Approach is established as best way to accomplish objective
  - Not been attempted on this scale before

Hourly Modeling

- Objective
  - Chronological simulation of operational planning and power system operation
  - Mimic
    - » Day-ahead unit commitment and scheduling based on load and wind generaton forecasts
    - » Real-time operation with actual wind and load
- How do we simulate the Eastern Interconnection in 2024?
  - Period-ahead planning (e.g. day-ahead unit commitment)
  - Real-time operations (at minimum of hourly granularity)
  - Operational structures
    - » Conventional control areas?
    - » Existing markets?

Discussion – Hourly Modeling

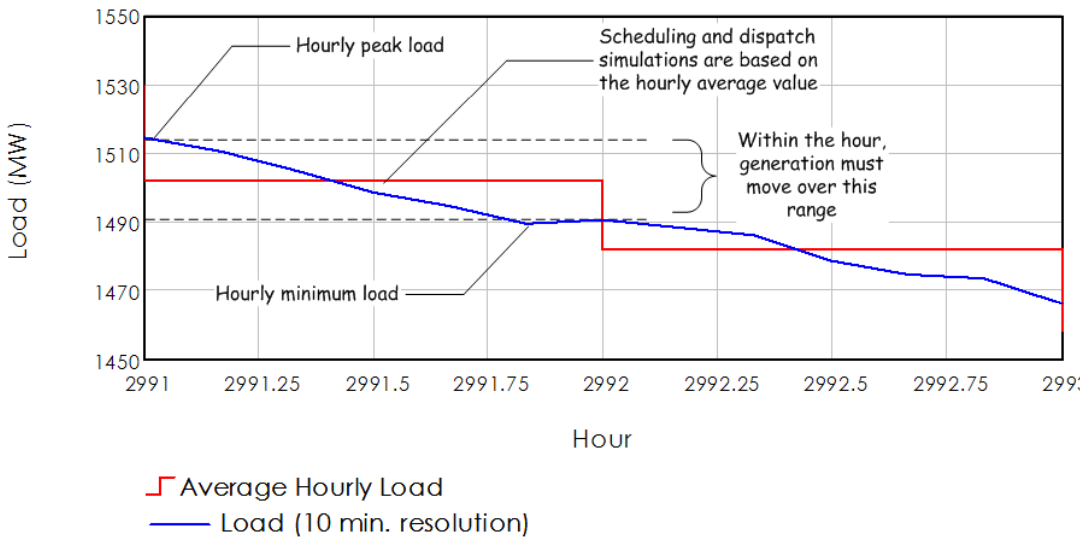
- PROMOD capabilities
  - Reserve modeling
    - Types
    - Treatment (e.g. variable by hour?)
  - Commit based on forecast, simulation based on actual quantities?
  - Features for treatment of uncertainty?
- Modeling Transactions
  - Day-ahead and “real time”
  - Relevant program features

Intra-Hour Impacts

- Objective
  - Determine operating reserves required to manage control area with wind generation
  - Feed requirements forward into hourly modeling
- Variability of wind generation adds to existing variability, increasing requirements for RT ancillary services
- Analytical approach
  - Based on high-resolution (< 10 min) load and wind generation data

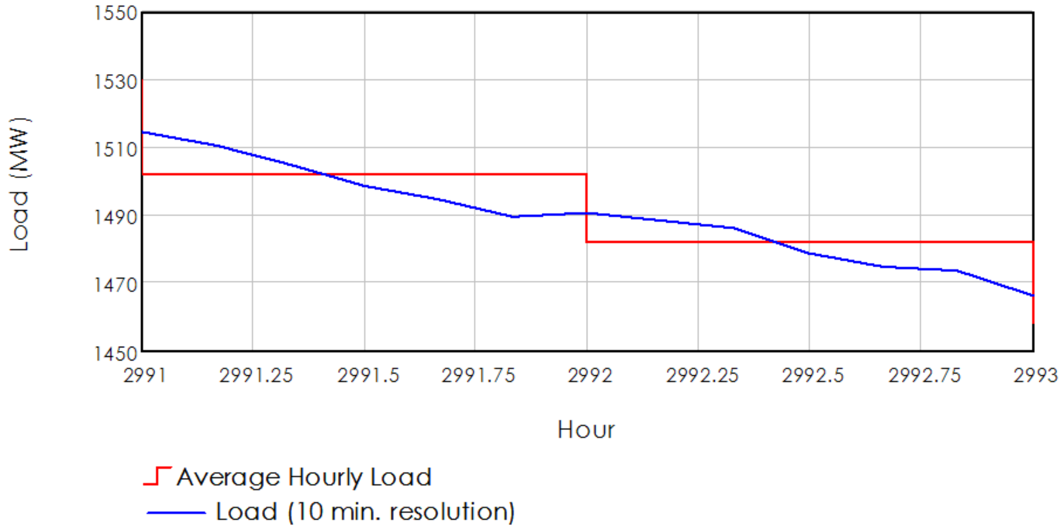
Determine "Basepoint" Schedule

- Assume base-loaded generation is equivalent to average hourly demand
- Calculate "flexibility" requirement as difference between actual (10 minut average) and schedule
- Average hourly values are what is modeled in production costing progra



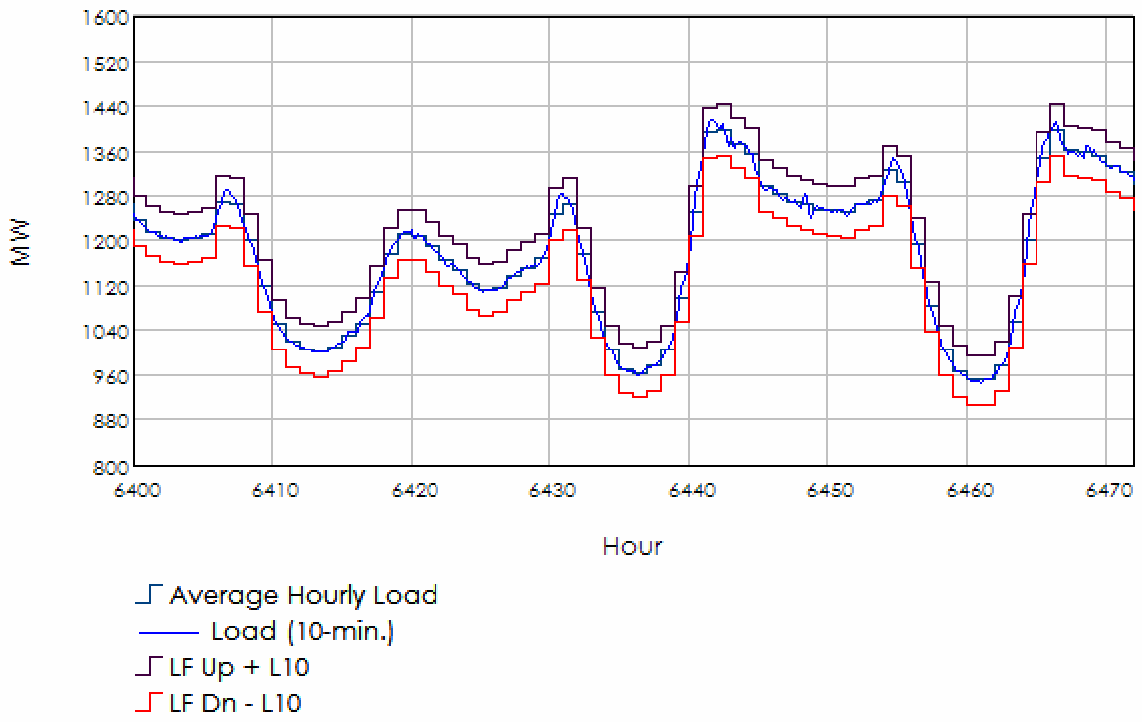
Over-the-Hour Ramping

- WECC hourly schedules consider a 20-minute ramping period over top of hour
- Ramping will assist with following of load during these periods
- Generation scheduled this way will have reduced ramping capability
  - 1 MW minute
  - 60 MW/hour ramping continuously
  - 20 MW/hour with WECC ramps



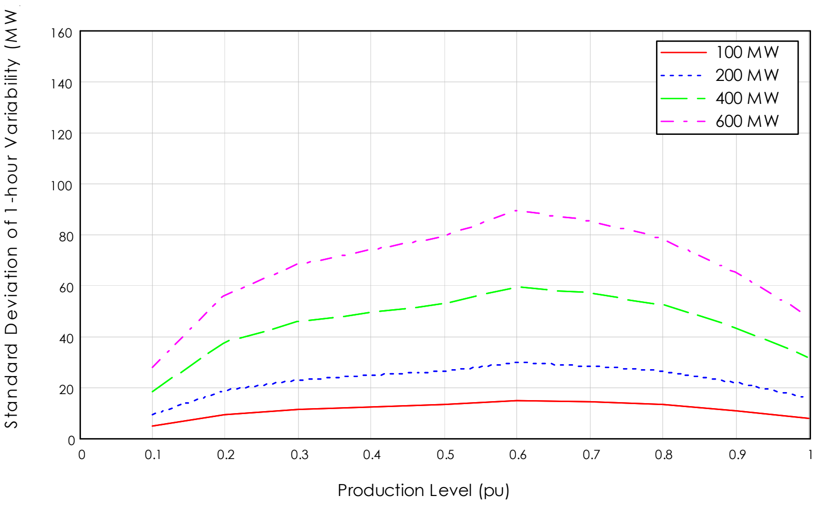
“Rule” for Determining Flexibility Requirement

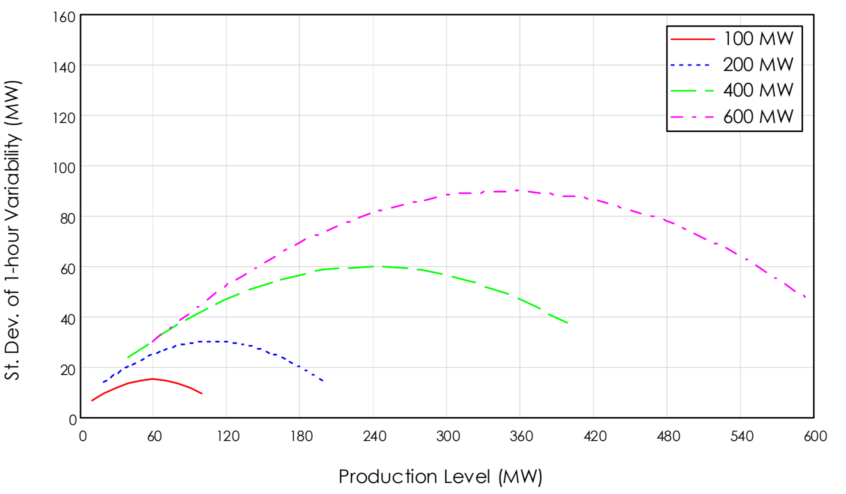
- Use short-term forecasts as input
- Adjust formula so that >90% of 10-minute values are within flexibility bands +/ L10
- Rule allows bands to vary by hour
- Flexibility may include both regulation and load following (e.g. Pacific Northwest)



Characterizing Wind Variability

- Wind generation may increase hourly flexibility requirements
- Rule can be augmented in consideration of wind generation
- Characterize variability over the hour as function or current production level
- Example: use statistics of hourly wind generation changes

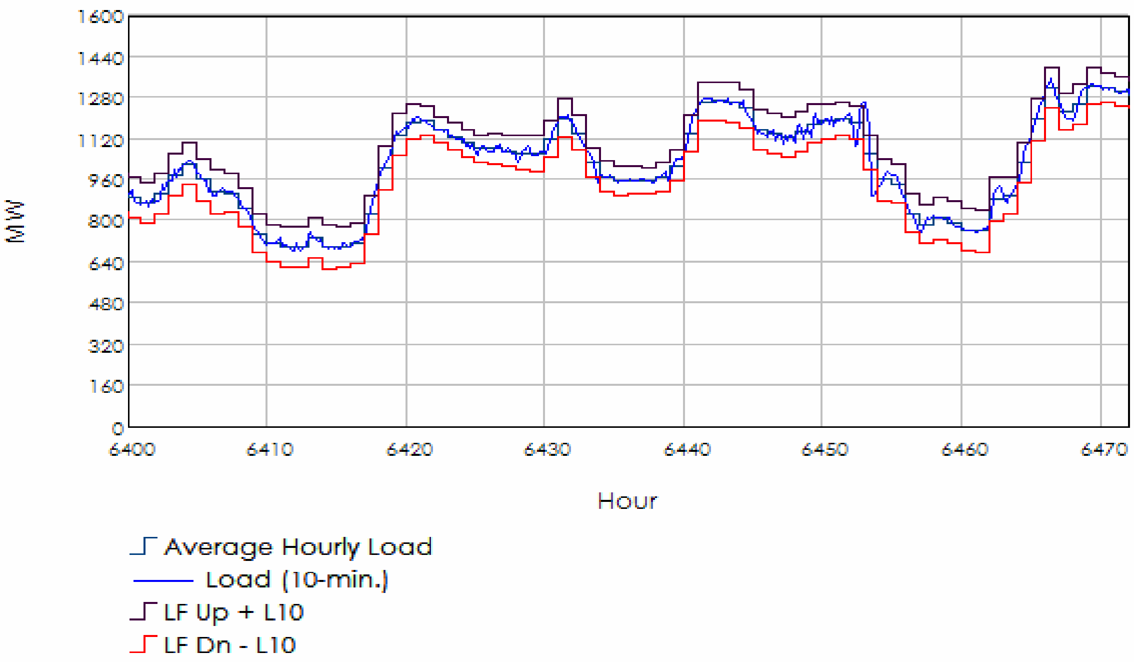




Load Following "Rule" with Wind Generation

- Flexibility rule includes term related to wind generation variability
- Coefficient k1 can be determined by "testing" rule over duration of data
- k1 is adjusted so that performance (CPS2) i equivalent to load-only case

$$F1_{h1} := F0_{h1} + k1 \cdot \left[15 - \frac{\left(HWind1_{h1-1} - 60\right)^2}{300} \right]$$



Impact of Short-Term Forecast Errors

- Reserves and hourly transactions must be established some time prior to operating hour (H)
- Short-term forecasts of load (and wind generation) at H – (lead time) are used to plan for hour H
- Expected errors in ST forecasts over (lead time) will affect machine capability required in hour H
- Because of flat schedules and hourly average values, this error appears as an "offset" over the entire hour H
- Result:
  - Variability is not affected, but deviation in basepoint scheduled must be covered with machine capability
  - Becomes additional "reserve" requirement due to statistical combination of load and wind generation forecast errors

Reliability Analysis

- GE MARS
  - Monte-Carlo based chronological reliability simulation
  - Now in use at MISO
- Objectives
  - Calculate ELCC for wind generation based on comparative LOLE cases
  - Zone-by-zone basis
- Input data
  - Network, resource, and load data input developed from PowerBase
  - Wind as load modifier

DATA, TOOLS, AND MODELS

Overview

- Primary Data Sources
  - NREL Eastern Mesoscale Database(+)
    - » 10 min data for ~600 GW of wind generation
    - » 2004, 2005, and 2006
    - » Imported network data from…
  - PowerBase
- Analytical Tools
  - SQL server for mesoscale data management and characterization
  - PROMOD IV – hourly production simulations
  - GE MARS (multi-area reliability analysis)

NREL Mesoscale Data

- Database description
- Metrics
- SQL database applications
- Import/export with PowerBase
- Sneak peek at some data

Status

Database now holds 2004 wind data and site information for 1325 sites

This data is held in approximately 3GB Microsoft SQL Server Database

Forecast data will follow, will be stored as 1 Hr Data

Network information – Load and wind injection bus information to be added

10 Minute Data

Site ID

Time Stamp

80m Wind Speed

100m Wind Speed

IEC Class 1 Curve at 80m

IEC Class 2 Curve at 80m

IEC Class 3 Curve at 100m

Power at Assigned IEC Class (see Site Info)

Plant Information

Plant ID Number

State

Latitude

Longitude

COE

Avg Wind Speed

Avg Capacity Factor

Plant Area

Avg Power Density

NamePlate

IEC Class

1 Hour Average Data

Site ID

Timestamp

Power

Count of Plants by Size

Plant Size (MW)	*Count*
0 -150	265
150 - 250	155
250 - 350	214
350 - 450	194
450 - 550	146
550 - 650	95
650 - 750	52
750 - 850	38
850 - 950	11
950 - 1050	57
1050 - 1150	54
1150 - 1250	29
1250 - 1350	12
1350 - 1450	3

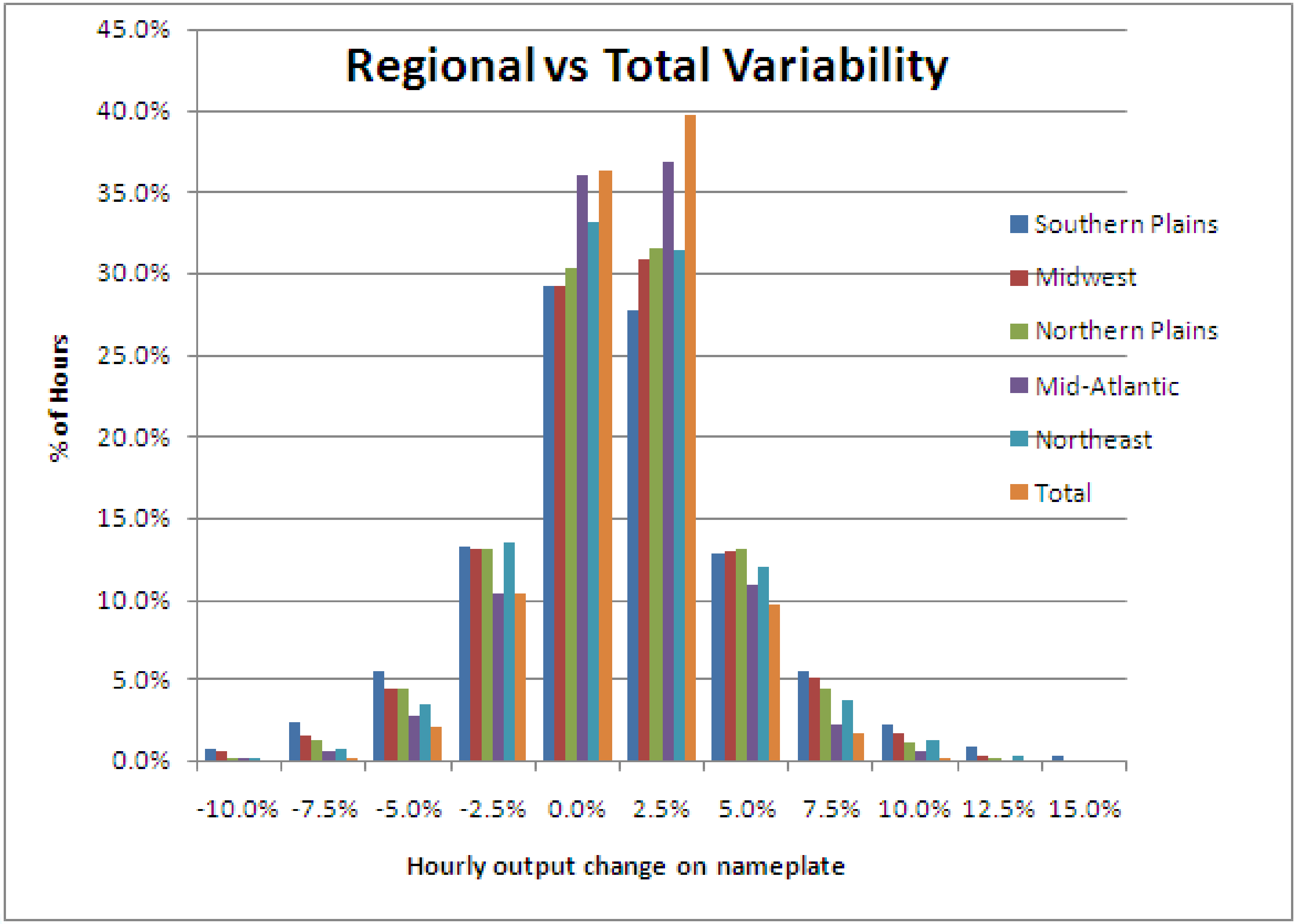
Number of Plants by Size and State

State	0 - 150	150 - 250	250 - 350	350 - 450	450 - 550	550 - 650	650 - 750	750 - 850	850 - 950	950 - 1050	1050 - 1150	1150 - 1250	1250 - 1350	1350 - 1450
Arkansas	11	6	2							1				
Colorado			2	3	1		1	1						
Connecticut	6	2												
Delaware	6		1											
Illinois		5	19	23	6	5	2	5	2	6	4	1	1	
Indiana		5	17	12	9	6	3	1		3	4	1		
Iowa		7	13	17	17	13	6	6	1	4	1	2	4	1
Kansas			6	12	10	10	5	3	1	1	11	5	2	
Kentucky	3		1	1	1									
Maine	37	4									1			
Maryland	7	2												
Massachusetts	18	1												
Michigan	9	13	12	5	5	1	3	1	1	3	1	2		1
Minnesota	1	9	33	22	22	13		4	1	4	7	4	1	
Missouri		1	4	4	2	5			1	1	1			
Montana	2	2	2	2	1				1	1				1
Nebraska		8	16	17	13	9	8	3		10	4	1		
New Hampshire	20	1												
New Jersey	5	2		1										
New Mexico	2	5	4	3	5		2		1	1	1			
New York	25	26	5	5	1		2	1			1			
North Carolina	6	2		1	1									
North Dakota		6	13	10	10	6	3	2		5	3	2		
Ohio		4	9	4	4	2	6	1		1	2	1		
Oklahoma	4	9	14	21	11	7		5		5	4	1	1	
Pennsylvania	48	7	1											
Rhode Island	4	3												
South Dakota	2	9	14	18	13	13	6	2	2	5	4	2	1	
Tennessee	7	1												
Texas			11	8	6	4	3	1	1	2	4	6	2	
Vermont	14	3												
Virginia	13	1	2											
West Virginia	15	2		1										
Wisconsin		8	14	4	8	1	2	1		4	1	1		

Total Plant Capacity by Size and State

State	0 - 150	150 - 250	250 - 350	350 - 450	450 - 550	550 - 650	650 - 750	750 - 850	850 - 950	950 - 1050	1050 - 1150	1150 - 1250	1250 - 1350	1350 - 1450
Arkansas	1342	1101	557							1049				
Colorado			541	1191	456		732	840						
Connecticut	685	346												
Delaware	688		330											
Illinois		1162	5776	9076	3021	2854	1357	3979	1747	6164	4370	1234	1291	
Indiana		1135	4963	4878	4564	3663	2181	823		3104	4456	1199		
Iowa		1595	3989	6895	8474	7798	4081	4762	919	4024	1107	2414	5083	1435
Kansas			1778	4936	4997	5918	3441	2418	906	1011	12153	5930	2581	
Kentucky	300		264	381	545									
Maine	4026	753									1084			
Maryland	769	345												
Massachusetts	1998	168												
Michigan	1029	2671	3508	1992	2470	578	2107	797	896	3085	1082	2369		1361
Minnesota	147	2036	9839	8973	10774	7726		3209	880	4075	7762	4777	1281	
Missouri		245	1316	1658	950	2907			878	1038	1147			
Montana	269	463	598	772	497				850	1025				1357
Nebraska		1875	4708	6792	6289	5279	5509	2273		10209	4366	1171		
New Hampshire	2188	183												
New Jersey	548	357		423										
New Mexico	203	1076	1161	1207	2396		1418		897	1038	1128			
New York	2756	4992	1373	1934	516		1377	825			1086			
North Carolina	642	386		425	546									
North Dakota		1267	4016	4035	4879	3500	2141	1570		5121	3222	2388		
Ohio		822	2715	1540	1892	1194	4098	795		969	2212	1207		
Oklahoma	400	1927	4179	8295	5336	4222		4016		5062	4361	1163	1291	
Pennsylvania	5517	1176	294											
Rhode Island	462	578												
South Dakota	271	1847	4312	7279	6376	7708	4247	1529	1772	5047	4480	2374	1304	
Tennessee	730	156												
Texas			3317	3142	2874	2440	2176	789	890	2046	4413	7196	2613	
Vermont	1537	482												
Virginia	1340	197	561											
West Virginia	1543	430		403										
Wisconsin		1611	4245	1597	3940	560	1397	753		4035	1125	1230		

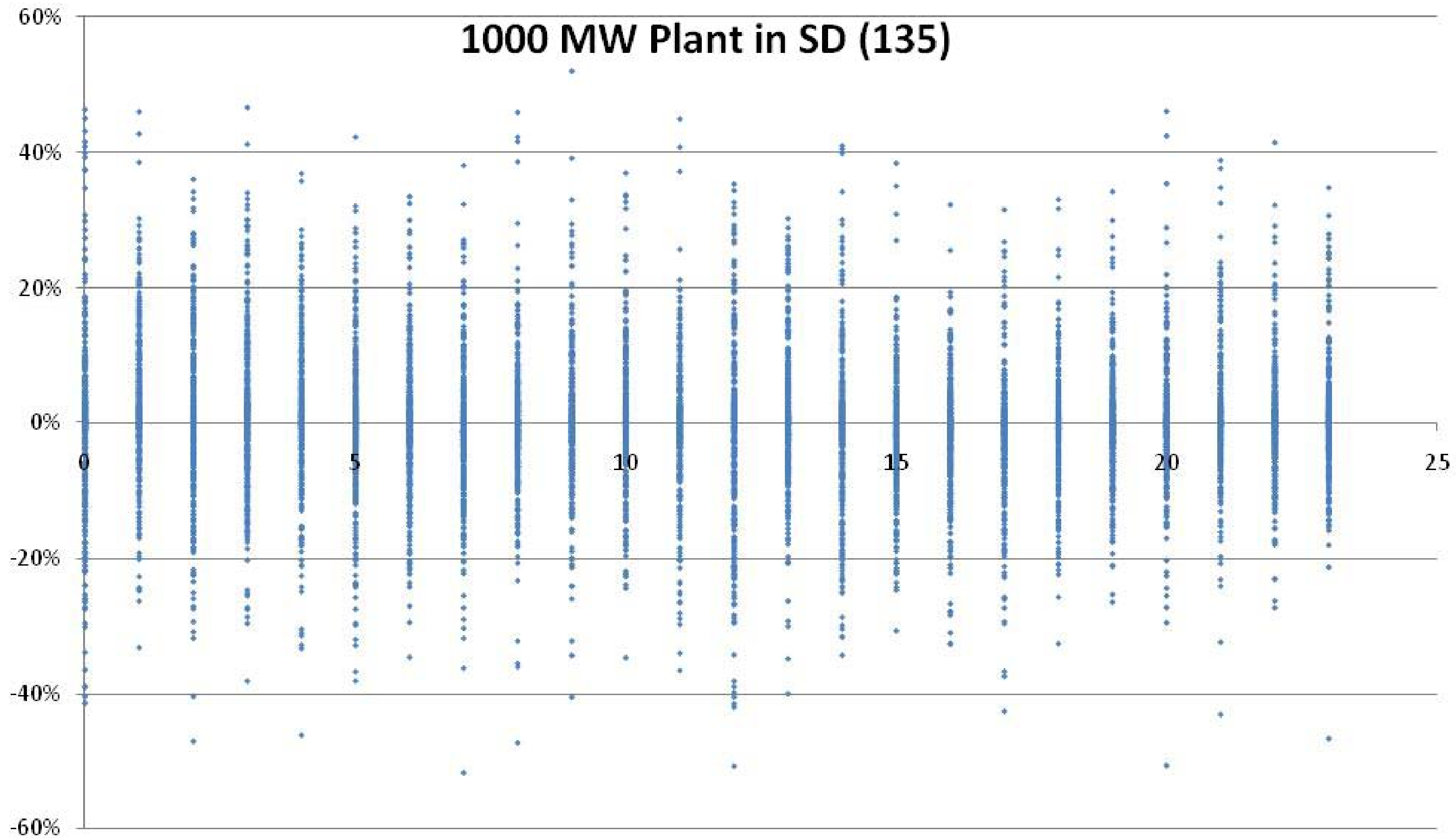
Hourly Variability



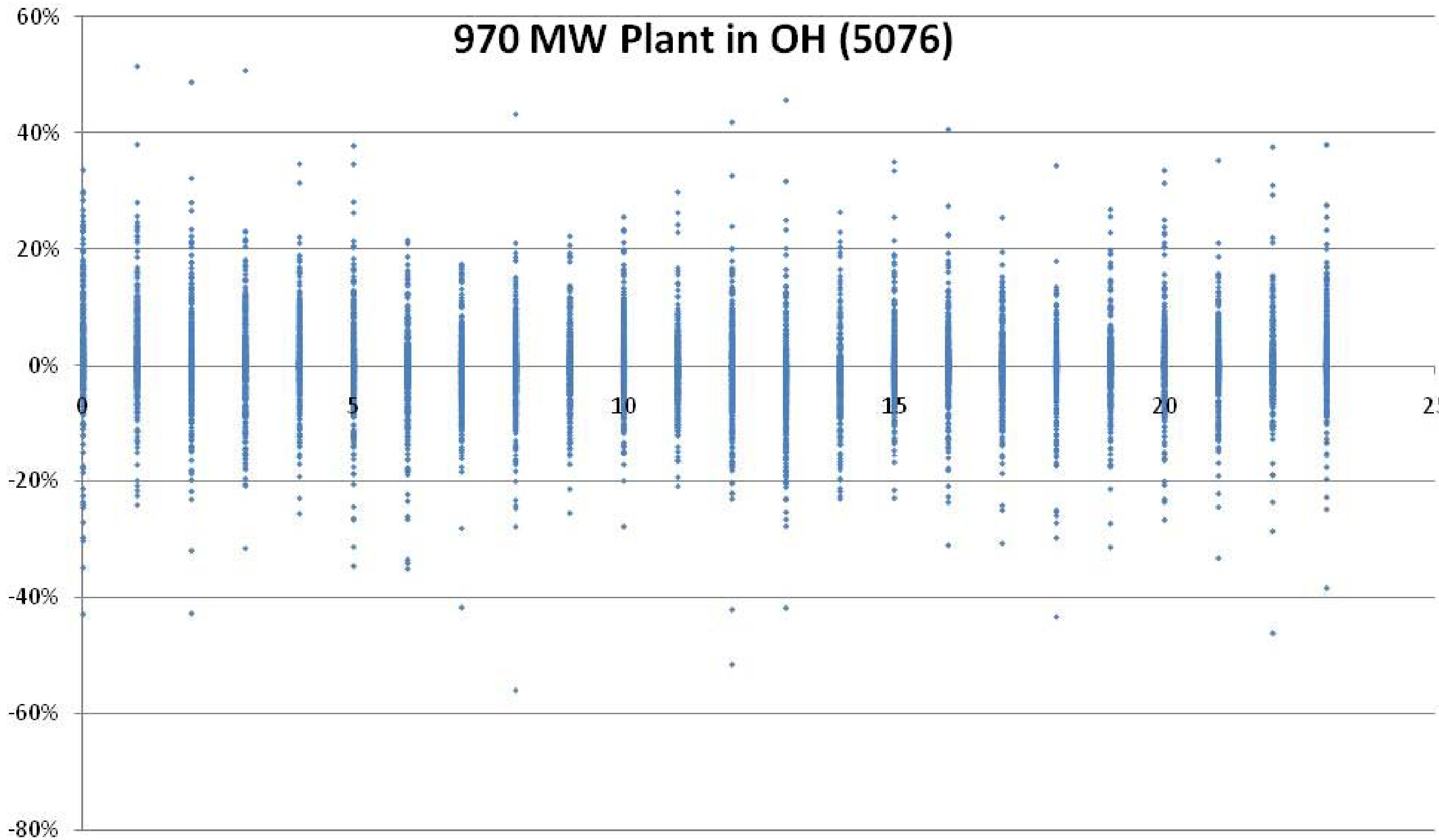
Variation Data

	Mid-Atlantic	Northeast	Midwest	Southern Plains	Northern Plains	Total	1000MW Plant (SD)	970 MW (OH)	2006 MN 25%
Namplate	18844	28309	136367	146688	249041	579249	1000	970	5689
Capacity Factor	23%	29%	29%	37%	37%	34%	41%	30%	42%
Ave Dn %	-1.9%	-2.2%	-2.6%	-2.8%	-2.5%	-1.8%	-6.8%	-4.7%	-3.4%
Ave Up %	1.9%	2.4%	2.5%	2.9%	2.4%	1.7%	7.0%	5.0%	3.4%
Ave Dn MW	-360	-637	-3583	-4117	-6159	-10349	-68	-46	-193
Ave Up MW	352	669	3463	4261	6016	9864	70	49	193
Max Dn %	-11.4%	-16.5%	-18.4%	-19.1%	-14.1%	-11.7%	-52%	-56.1%	-25.3%
Max Up %	14.1%	14.6%	18.1%	23.2%	17.3%	9.7%	52%	51.5%	23.5%
Max Dn MW	-2145	-4672	-25054	-28063	-35012	-67654	-516	-544	-1438
Max Up MW	2664	4138	24631	34033	43070	56335	520	499	1340

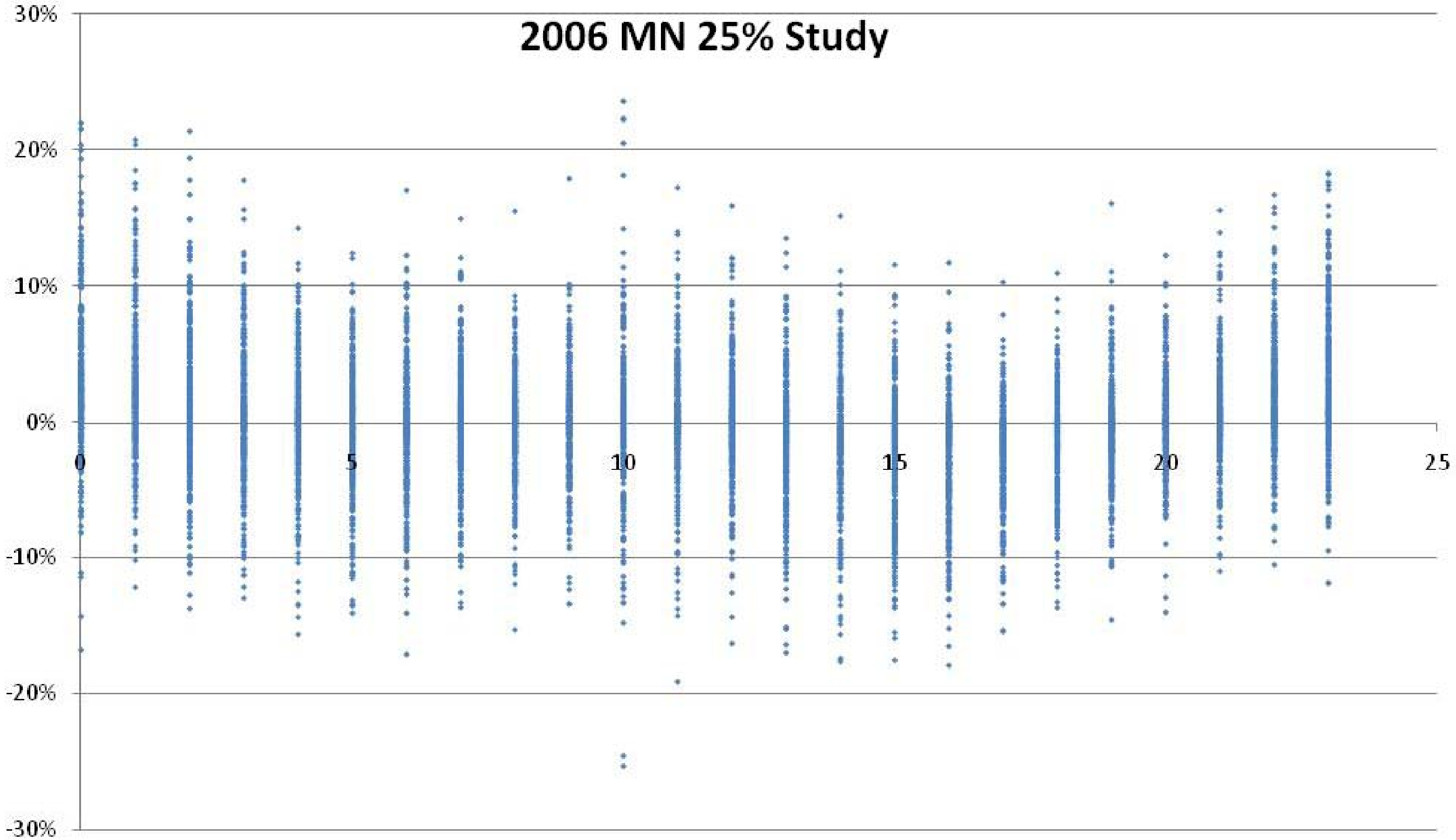
Hourly Variation for a Large plant vs Hour of the day



Hourly Variation for a Large plant vs Hour of the day

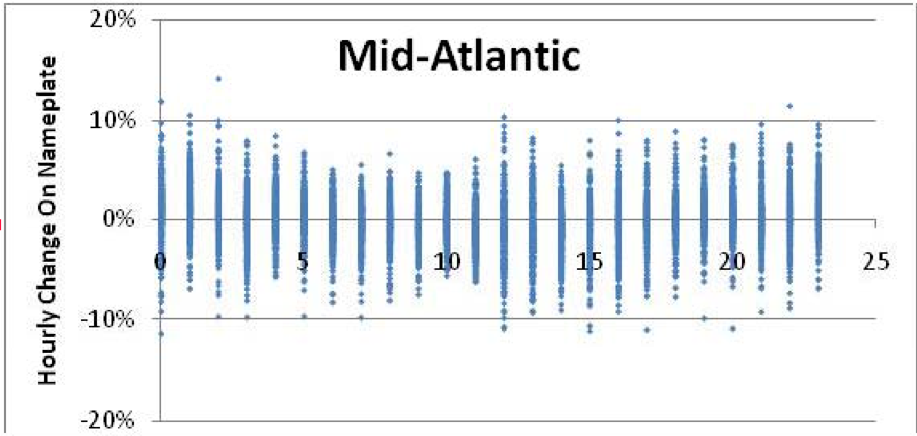


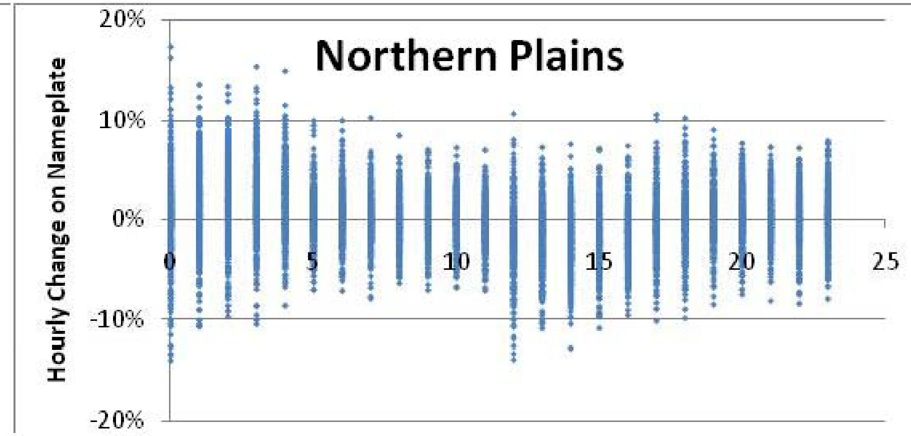
All Data from 2006 MN Study

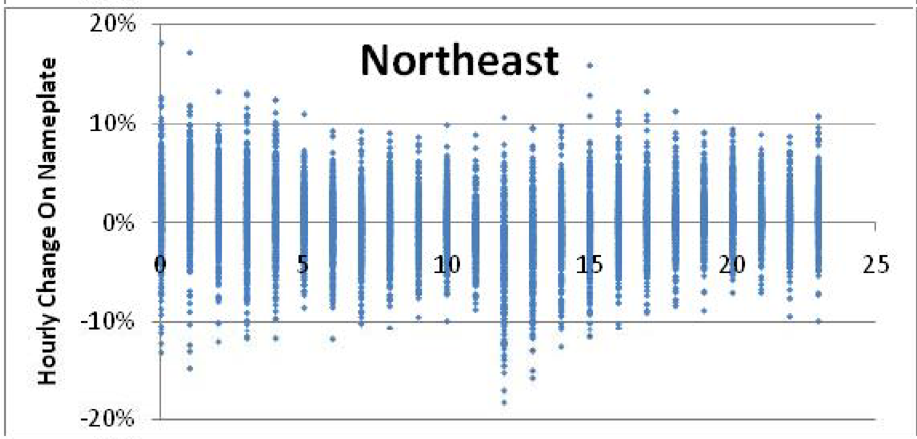


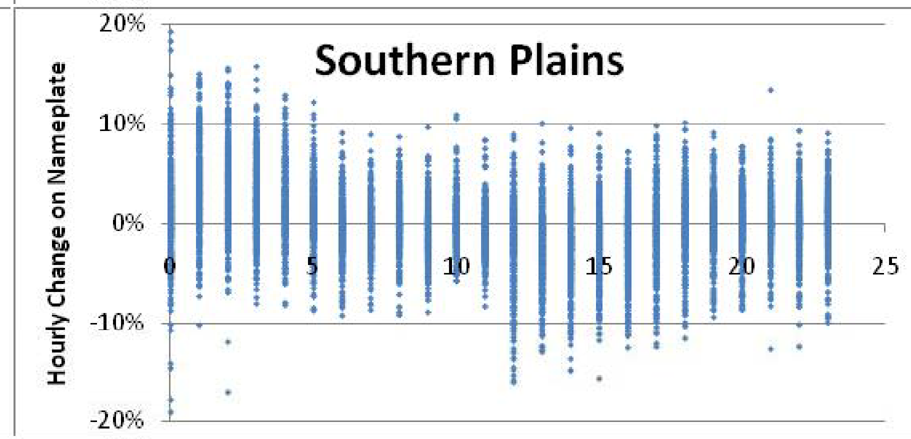
Following Slide

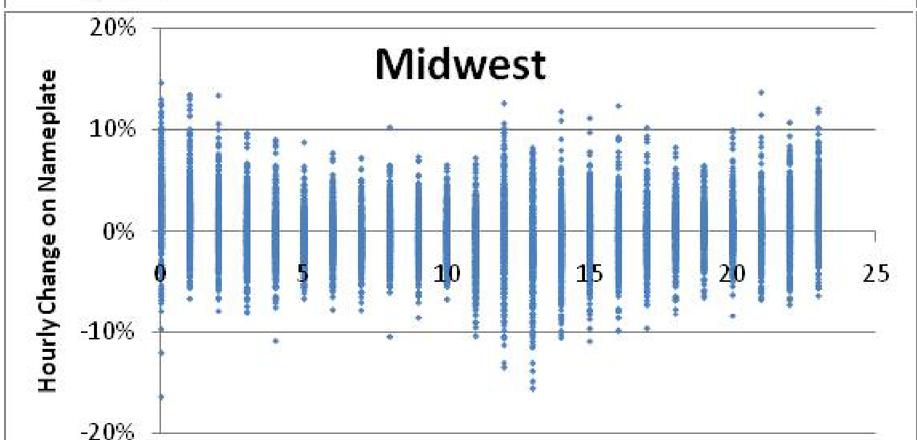
- Hourly variability by region from NREL mesoscale data

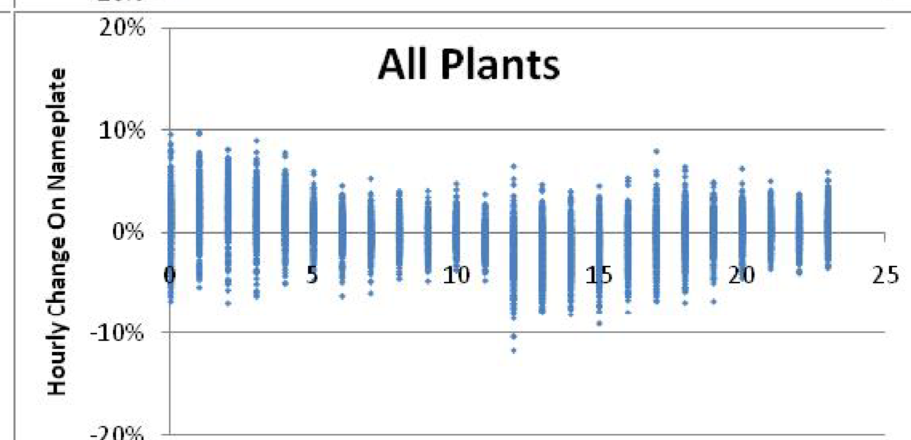

Mid-Atlantic
Hourly Change On Nameplate
20%
10%
0%
-10%
-20%
0
5
10
15
20
25


Northern Plains
Hourly Change on Nameplate
20%
10%
0%
-10%
-20%
0
5
10
15
20
25


Northeast
Hourly Change On Nameplate
20%
10%
0%
-10%
-20%
0
5
10
15
20
25


Southern Plains
Hourly Change on Nameplate
20%
10%
0%
-10%
-20%
0
5
10
15
20
25


Midwest
Hourly Change on Nameplate
20%
10%
0%
-10%
-20%
0
5
10
15
20
25


All Plants
Hourly Change On Nameplate
20%
10%
0%
-10%
-20%
0
5
10
15
20
25

PowerBase & PROMOD

- Ventyx

JCSP Update and Status

- MISO

JCSP 2024 Case Details

Transmission Planning Methodology

- MISO

Reliability Analysis with GE MARS

- MISO

LOLE Background

- Loss of Load Expectation (LOLE) is the measure of an area's inability to meet it's load given the probability of random generation forced outages and limited tie line support from neighboring systems
- Less than 1 day in 10 years (or 0.1d/yr) is often the criteria in which areas/zones are evaluated

LOLE Software & Data

- MARS is a Multi-Area Reliability Simulation Program from the General Electric Company which utilizes a sequential Monte Carlo simulation to calculate loss of load indices
- A MARS LOLE model can be constructed from the same PROMOD PowerBase data set that is used in production cost simulations

MidwestISO
Energizing the Heartland

LOLE Zones

- LOLE models operate with an equalized transportation style model as oppose to using a fully detailed transmission model
- Therefore a collection of zones and interfaces are used to capture the capabilities and limitations of the transmission system

Zonal Import Limits

- The Effective Zonal Import Limits required in the MARS model can be determined from PROMOD analysis
  - Utilizing penalty factors assigned to zones whose maximum import capability is being evaluated to force import flows
  - Monitoring the transmission ties between zones and grouping them as interfaces

ISSUES AND ASSUMPTIONS

Completing the "Picture" for 2024

- Hourly profile and network/resource data only part of PROMOD input
- Assumptions must be made regarding a variety of matters related to case setup
- Some issues will be more difficult than others!
- Decisions must be reached well before TRC Meeting #3

Overview of Issues & Assumptions

- Market Structure(s)
- Treatment of non-market areas
- Representation of Canadian utilities
- Modeling questions
- Critical inputs

Markets

- Market structure may have influence on
  - Operating reserve requirements and estimation from high-resolution data
  - Hurdle rates between areas
- How many markets in 2024?
- What products will be available in each?
- Should we assume uniformity, or is there reason to vary the market model across the Eastern Interconnection footprint?

Other Structural Questions

- What about non-participants?
- What about Canadian Utilities

Modeling Questions & Challenges

- Production simulations conducted at hourly granularity
- Requirements for operations within the hour represented as constraints
  - Contingency reserves
  - Regulating reserves
- Methodology for estimating in-hour reserves for PROMOD?

Modeling Questions & Challenges

- Forecast horizon
  - Presently, day-ahead optimization/commitment is the norm
  - Forecast errors lead to sub-optimal commitments
  - With significant wind generation
    - » Will DA forecast errors with significant wind generation be too large to permit reasonable optimization?
    - » Is a shorter commitment horizon warranted? (e.g. All-Ireland Grid Study)
- HVDC line modeling
  - Based on JCSP, large a significant component of transmission overlay
  - What will be the “rules” for scheduling transactions and services at the terminals?

Critical Inputs

- Fuel prices
- Ramp rates
- Unit cycling limits
- Minimum loading
- Carbon, other emissions costs
- Market hurdle rates

Summary

- Modeling assumptions and inputs will become critical path following TRC Meeting #2
- Topics will be discussed again at that meeting
- Project team will provide recommendations for review

DISCUSSION & SUMMARY

Wrapping Up

- Miscellaneous discussion
- Review of Action Items
- Meeting follow-up
- Next meeting